Transportation Literature Search

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Construction Vibration Impacts on Early-Age Concrete

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WHRP Geotechnics Technical Oversight Committee

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Transportation Literature Searches are prepared for WisDOT technical staff in highway development, construction and operations. The bibliography below is representative, rather than exhaustive, of available studies on the topic. Primary online resources for the literature searches are the Transportation Libraries Catalog (TLCat), the Transportation Research Information Service (TRIS Online), and various academic and scientific databases. Online copies of publications are noted when available. Hard copies of all cited literature may be obtained through the WisDOT Library.

KEYWORDS
Keywords used in searches of Web-based databases included: fresh, new, concrete, vibration, pile driving, damage, fresh concrete, green concrete, frequency, amplitude.

LIBRARY OF CONGRESS DESCRIPTORS
Additional keywords and descriptors emerging from searches included: Early age concrete, Noise control, Foundations, Construction, Acoustic curtain, Noise, Sound level, Laboratory tests, Shaking table test, Ultrasonic tests, Man-made vibrations, Ground vibrations, Construction vibrations, Sheetpile driving, Amplification, Vibration criteria.

CITATIONS – Construction Vibration

Title: Potential low-frequency ground vibration (<6.3Hz) impacts from underground LRT operations
Author(s): Wolf, S.
Date: October 23, 2003
Doc ID/URL: Journal of Sound and Vibration, Vol. 267, No. 3, pp. 651-661
Description: 11 pages
Contents: Vibration sensitive research activities at the laboratories of the University of Washington (UW) Physics and Astronomy Building (PAB) were a critical issue for the design of the Sound Transit Link Light Rail LRT system in Seattle, Washington. A study was conducted to measure and predict low frequency ground vibration generated by the LRT operations. The University's concern was an on-going research experiment in gravity, which had sensitivity to vibration below 6.3Hz. The experiment was located on an independent concrete slab in an area cut-out from the building foundation with no connection to the building structure. Another concern was the planned future construction of a Life Sciences Center with vibration sensitive test equipment. This paper presents the results of a study to estimate the ground displacement at these buildings using empirical measured data of a similar deep tunnel transit system and finite difference modelling analysis.

Title: Effects of Vibration and Sound During the Installation of Deep Foundations
Author(s): Reddy, DV; Tawfiq, KS
Date: August, 2000
Doc ID/URL: Florida Department of Transportation, WPI 0510794; State Job 99700-3361-010
Description: 363 pages
Contents: This project addresses two frequent construction problems associated with deep foundation installation: i) The effect of vibrations induced during the installation of drilled shafts, on "green concrete," defined as freshly placed and maturing concrete within 24 hours after initial placement; and ii) Noise levels during pile driving due to the low threshold of human perception. The laboratory investigation addressed the determination of the damage

threshold particle velocity by shake table vibration testing of concrete cylinders at predetermined time delays (0, 1, 2, 3, 4, and 24 hr), ultrasonic testing for compression moduli before compressive strength testing, and testing of cored cylinders from full scale drilled shafts. The principal finding from laboratory testing was that construction vibrations that produce particle velocities less than 8 in./sec would not have any effect on the compressive strength or compression modulus of the concrete aged between the time of placement to the first 24 hr. In the field investigation, the peak particle velocities during drilled shaft were monitored to determine their effect on "green concrete." The principal findings from the field study are as follows: i) Vibrations, with peak particle velocities of up to 2.5 in./sec do not cause damage to the "green concrete" at a distance of two times the shaft diameter and beyond; and ii) In general, a spacing of three times the shaft diameter would be a safe specification to ensure no concrete damage due to shaft vibration. In Part 2, the propagation of noise generated from the driving of concrete piles was measured and the effect of mitigation through the use of an acoustic curtain evaluated. This project focused on the use of an acoustic curtain constructed of a combination of absorptive and reflective materials to provide a complete enclosure of the source to mitigate the propagation of the inherent noise.

Title: Ground vibrations from sheetpile driving in urban environment: measurements, analysis and effects on buildings and occupants
Author(s): Athanasopoulos, G.A.; Pelekis, P.C.
Date: July, 2000
Doc ID/URL: Soil Dynamics and Earthquake Engineering, Vol. 19, No. 5, pp. 371-387
Description: 17 pages
Contents: Following a comprehensive review of the subject of man-made ground vibrations, measurements of ground vibration caused by vibratory sheetpile driving in recent soil deposits are reported in terms of particle velocities vs. distance from the source of vibration. The measurements were conducted on paved surfaces and sidewalks in the inner urban environment. Reconstructed particle displacement paths indicated, predominantly, vertical vibrations of the Rayleigh type. The attenuation rate of vibrations with distance was compared to published results of other studies and satisfactory agreement was found to exist. Values of particle velocity measured in this study, however, were lower than corresponding values of other studies under comparable values of rated vibratory kinetic energy. This is possibly due to different soil conditions. Average and upper bound linear log-log attenuation relationships are proposed, which fit the results of measurements and are representative of the conditions likely to be encountered in the urban environment. Measurement of vibrations on higher floors of multistory reinforced concrete buildings indicated a significant amplification of vertical vibration and an average curve for amplification magnitude vs. floor level was fitted to the results of measurements. A comparison of measured values of vibration with the observed performance of buildings and with damage threshold values suggested by existing codes and standards indicated that the latter do not provide safety against damage caused by vibratory densification of loose sandy soils. On the other hand, the existing criteria for human exposure to vibrations in buildings, according to the results of this study, seem to adequately define the degrees of human discomfort.

Title: Vibration in structures adjacent to pile driving
Author(s): Theissen, John R. and Wood, William C.
Date: July, 1982
Doc ID/URL: *Engineering Bulletin 60*, July 1982, pp. 5-20
Description: 16 pages
Contents: Not available

Title: Field Study of Pile Driving Effects on Nearby Structures
Author(s): Holloway, D. M., Y. Moriwaki, E. Densky, G. H. Moore, and J. Y. Perez.
Date: October, 1980
Doc ID/URL: American Society of Civil Engineers, Preprint No. 80-175, pp. 63-100
Description: 38 pages
Contents: Not available

Title: Vibrations Associated with Pile Driving
Author(s): Heckman, W. S., and D. J. Hogerty
Date: December 1978
Doc ID/URL: Journal of the Construction Division, American Society of Civil Engineers, Vol. 104, No. CD-4, pp. 385-394
Description: 10 pages
Contents: Not available

Title: Attenuation of ground vibration
Author(s): Dym, Clive L.
Date: April, 1976
Doc ID/URL: *Sound and Vibration*, April 1976, pp. 32-34.
Description: 3 pages
Contents: Not available

Title: Effects of Foundation Construction or [sic] Nearby Structures
Author(s): D'Appolonia, D. J.
Date: June, 1971
Doc ID/URL: Proceedings Fourth Pan American Conference on Soil Mechanics and Foundation Engineering, Vol. 1, pp. 189-236, San Juan Puerto Rico
Description: 48 pages
Contents: Not available

Title: Vibrations caused by pile driving: [annotated bibliography]
Author(s): Ferahian, R.H.
Date: March, 1968
Doc ID/URL: National Research Council-Ottawa, March 1968
Description: 10 pages
Contents: Not available

Title: Damage effects of pile driving vibration
Author(s): Wiss, J.F.
Date: 1967
Doc ID/URL: *Structural construction: 5 reports*, Highway research record 155, 1967, pp. 14-20
Description: 7 pages
Contents: Not available

Title: Concrete structure and construction vibration
Author(s): Akina, K.P. and Dixon, D.E.
Date: Not available
Doc ID/URL: *Vibrations of concrete structures* (SP-60), American Concrete Institute, p. 213-247
Description: 35 pages
Contents: Not available

CITATIONS – Fresh Concrete, Vulnerability, Effects Upon

Title: Effect of Vibration on Concrete Strength During Foundation Construction
Author(s): Tawfiq, K; Abichou, T
Date: September 2, 2003
Doc ID/URL: Florida Department of Transportation, final report
Description: 39 pages
Contents: Many studies have been conducted on the effect of construction vibrations on properties of freshly placed concrete. This study was concerned with the drilled shaft construction and its effect on the green concrete. The differences between the common construction vibrations and those produced during drilled shaft construction are the amplitudes and duration of vibrations. To characterize the type of vibrations induced during drilled shaft construction, a full scale field testing was conducted using a typical steel casing. The peak particle velocities (ppv) were recorded and empirical relationships were suggested to predict the velocity values on the surface and in the ground along the penetration depth of the shaft. Laboratory testing was conducted to determine the effect of the ppv and different durations of vibration on green concrete properties. The duration of vibration used in this study included the initial and the final time setting. If vibrations took place before initial time setting, the concrete would suffer a noticeable segregation especially for samples subjected to ppv of 2 in/sec. However, the strength measurements were higher at this velocity. When the green concrete was subjected to ppv of 2 in/sec during the period of initial to final time setting, the strength was decreased. This trend was true for all samples subjected to other ppv values. Therefore, it was suggested that for a period equal to the final time of the concrete there should be no vibrations allowed within a distance of 3 shaft diameter. Additionally, the ppv should not exceed 2 in/sec at the suggested distance.

Title: Dynamic Property Determination for Early-Age Concrete
Author(s): Jin, X; Li, Z
Date: September, 2001
Doc ID/URL: ACI Materials Journal, Vol. 98, No. 5, pp. 365-370
Description: 6 pages
Contents: Test results are reported of the dynamic modulus (DM) elasticity and Poisson's ratio of concrete at early age by means of nondestructive evaluation. The DM was measured by a new test apparatus that includes a free-free boundary vibration chamber and a dynamic resonance measurement system with a fast Fourier transform analyzer. The measurement was conducted on concrete cylinder specimens. The DM and Poisson's ratio were calculated using the first 2 natural frequencies of a cylinder. The measured dynamic response showed good consistency and reproducibility. This method enables a measurement of progressive changes in the stiffness of the concrete without damaging the specimen and provides reliable values of DM. It is found that the age of concrete has a significant influence on resonance frequencies; herein, the resonance frequencies shift from lower to higher values in a regular pattern with the age of concrete.

Title: Acceptable shock and vibration limits for freshly placed and maturing concrete
Author(s): Hulshizer, Allen J.
Date: 1996
Doc ID/URL: *ACI Materials Journal*, 1996, pp. 524-533
Description: 10 pages
Contents: Not available

Title: Behavior of fresh concrete during vibration
Author(s): ACI Committee 309, American Concrete Institute
Date: 1993
Doc ID/URL: Manual of Concrete Practice. American Concrete Institute: Detroit, 1993
Description: book, 19 pages
Contents: Not available

Title: An investigation on the effect of vibration on the workability of fresh concrete using a vertical pipe apparatus
Author(s): Tattersall, G.H. (University of Sheffield)
Date: March, 1989
Doc ID/URL: MC, No. 146
Description: Not available
Contents: Using an apparatus in which fresh concrete is allowed to flow out of a vertical pipe while being vibrated, it is confirmed that under vibration and at low shear rates the material behaves as a Newtonian liquid. Effectiveness of vibration is to be assessed in terms of maximum velocity but there is a threshold amplitude below which, and an upper limiting frequency above which, vibration has no effect. It is shown that fluidity determined by this method correlates with fluidity determined earlier by an entirely different method.

Title: The effect of vibration on the rheological properties of fresh concrete
Author(s): Tattersall, G.H. (University of Sheffield)
Date: June, 1988
Doc ID/URL: MC, No. 143
Description: Not available
Contents: Using a set-up in which the bowl of a two-point workability test apparatus was mounted on an electromagnetic vibrating table, measurements were made on unvibrated fresh concrete and on the same samples under vibration. It was shown that when vibration is applied the flow properties of fresh concrete are no longer represented by the simple linear Bingham model but approximate to those of a power law pseudoplastic with zero yield value. At very low shear rates behaviour approximates to that of a Newtonian fluid and, subject to the exceeding of a small threshold condition, fluidity decreases as a simple exponential function of the maximum velocity of vibration.

Title: How do blasting, jarring, and other shock vibrations affect fresh concrete? New study suggests transitory vibration limits may be relaxed
Author(s): Not available
Date: February, 1985
Doc ID/URL: *Concrete Construction*, Feb. 1985, pp. 214-215
Description: 2 pages
Contents: Not available

Title: Field Study of Pile Driving Effects on Nearby Structures
Author(s): Holloway, D. M., Y. Moriwaki, E. Densky, G. H. Moore, and J. Y. Perez.
Date: October, 1980
Doc ID/URL: American Society of Civil Engineers, Preprint No. 80-175, pp. 63-100
Description: 38 pages
Contents: Not available

Title: Effects of shocks on fresh and new concrete
Author(s): Bonzel, J. and Schmidt, M.
Date: 1980
Doc ID/URL: *Beton:Herstellung Verwendung*, vol. 30, no.9, 1980, p. 333-337. English translation of the original.
Description: 5 pages
Contents: Not available
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Title: The effect of coal mill vibration on fresh concrete
Author(s): Krell, William C.
Date: December, 1979
Doc ID/URL: *Concrete International*, Dec. 1979, pp. 31-34
Description: 4 pages
Contents: Not available

Title: Effects of Foundation Construction or [sic] Nearby Structures
Author(s): D'Appolonia, D. J.
Date: June, 1971
Doc ID/URL: Proceedings Fourth Pan American Conference on Soil Mechanics and Foundation Engineering, Vol. 1, pp. 189-236, San Juan Puerto Rico
Description: 48 pages
Contents: Not available

Title: The effect of vibrations on freshly poured concrete
Author(s): Bastian, C.E.
Date: 1970
Doc ID/URL: *Foundation facts*, Vol. 6, No. 1, 1970, pp.14-17
Description: 4 pages
Contents: Not available

Title: The effects of continuous vibration of concrete during initial set
Author(s): Ornowski, Joseph B.
Date: 1967
Doc ID/URL: *A synopsis of some recent developments relating to the construction industry*, Engineering Experiment Station, University of Arizona, EES series report no. 14, 1967, p. 40-42
Description: 3 pages
Contents: Not available

CITATIONS – Research in Progress or Not Yet Published

Title: Effect of Ground Vibration While Foundation Concrete is Setting
Author(s): Engineering Forensics Research Institute, Rose-Hulman Institute of Technology (http://www.rose-hulman.edu/~sutterer/EFRI/) (corporate author); Jim Hanson, investigator
Date: Not available as of Summer, 2004
Doc ID/URL: http://www.rose-hulman.edu/~sutterer/EFRI/reu_proj.htm#Ground%20Vibration
Description: Research in progress
Contents: While setting, fresh concrete is vulnerable to damage due to vibration, and damage is likely to affect the ultimate strength attained by the concrete. The fast pace of modern construction projects increases the possibility that soil compaction takes place adjacent to freshly placed concrete for foundations. Without better understanding of the impact of these vibrations, any concrete failure in a foundation will likely be attributed to the ready mix producer. Therefore, this project will quantify the actual impact that various levels of vibration at various stages of set will have on the ultimate strength attained by the concrete. Therefore, this project has a large scale laboratory program. In order to link the amount of vibration applied in the lab to the amount of vibration that can be seen in the

field, data about the energy of vibration for soil compaction must be acquired through literature or field measurement.

Title: The Effects of Vibrations and Sound Induced during the Installation of Deep Foundations
Author(s): Center for Marine Structures and Geotechnique, Florida Atlantic University (corporate author)
Date: Not available
Doc ID/URL: http://www.civil.fau.edu/cfmsg.htm#1
Description: Final report in progress
Contents: This project addressed two frequent construction problems associated with deep foundation installation: i) The effect of vibrations induced during the installation of drilled shafts, on “green concrete”, defined as freshly placed and maturing concrete within 24 hours after initial placement, and ii) Noise levels during pile driving due to the low threshold of human perception. The laboratory investigation addressed the determination of the damage threshold particle velocity by shake table vibration testing of concrete cylinders at predetermined time delays (0,1,2,3,4, and 24 hours), ultrasonic testing for compression moduli before compressive strength testing, and testing of cored cylinders from full scale drilled shafts. The principal finding from laboratory testing was that construction vibrations that produce particle velocities less than 8 in./sec would not have any effect on the compressive strength or compression modulus of the concrete aged between the time of placement to the first 24 hour. In the field investigation, the peak particle velocities during drilled shaft were monitored to determine their effect on "green concrete". The principal findings from the field study are as follows: i) Vibrations, with peak particle velocities of up to 2.5 in./sec do not cause damage to the “green concrete” at a distance of two times the shaft diameter and beyond. ii) In general, a spacing of three times the shaft diameter would be a safe specification to ensure no concrete damage due to shaft vibration. In Part 2, the propagation of noise generated from the driving of concrete piles was measured and the effect of mitigation though the use of an acoustic curtain evaluated. This project focused on the use of an acoustic curtain constructed of a combination of absorptive and reflective materials to provide a complete enclosure of the source to mitigate the propagation of the inherent noise. In the field, a full-scale experiment was conducted by evaluating noise levels generated from the installation of concrete piles, with and without the aid of the acoustic curtain, a reinforced polyvinyl chloride outer shell for added mass, with a specially developed inner lining of 2 inch thick fiber glass acoustic insulation (1.5 lb/ft2). The results indicated that noise levels were reduced by up to 10dB, with the curtain enclosing the diesel hammer. Further research is recommended.